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DRD JHU I - UVS

CALIBRATION PLAN FOR ULTRAVIOLET SPECTROMETER EXPERIMENT S169

Contract No. NAS 9-11528 - Task I

22 September 1971

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From: Wm. G. Fastie

Subject: Calibration Plan for Ultraviolet Spectrometer Experiment S169.

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DRD JHU I - UVS

CALIBRATION PLAN

FOR

ULTRAVIOLET SPECTROMETER EXPERIMENT

S169

Contract No. NAS 9-11528

Task I

Approved by:

MSC Contracting Officer
Houston, Texas 77058

Approved by:

Wm G Fastie

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22 September 1971

III

CALIBRATION PLAN

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CALIBRATION PLAN

Apollo 17 UV Spectrometer (S169)

1. Introduction - Facility and Method.

1.1 The calibration test equipment (CTE) which will be employed to calibrate completely assembled and flight-ready Apollo UV Spectrometers consists of a vacuum system in which the UVS can be installed (Fig. 1). A premonochromator produces a monochromatic beam at any desired wavelength from a UV source. This beam can be focused by an adjustable transfer mirror to any point on the entrance slit of the UVS. The transfer mirror (M_T) can also direct the beamto one or both of two absolutely calibrated reference photomultiplier tubes ($RPMT_1$ and $RPMT_2$) to determine the number of photons ($I_{o\lambda}$) which enter the UVS. A movable mirror rhomb (M_R) is also provided to intermittently monitor the number of photons in the beam when the beam is centered on the entrance slit. The mounting bracket for the UVS can be tilted in two axes so that a number of small areas of the grating can be illuminated by the calibrated beam to make it possible to determine the integrated transmission of the spectrometer at each wavelength and for each area of the entrance slit.

During these operations the output of the UVS will be monitored by the Bench Test Equipment (BTE) with its dual outputs (Digital line printer and Brush strip chart recorder). The UVS output may also be recorded on digital tape for future reference.

Five different wavelengths, three slit areas and five grating areas will be measured, for a total of seventy-five measurements of $I_{o\lambda}$. At each wavelength position, the fifteen values of $I_{o\lambda}$ will be averaged and the fifteen BTE signals will be averaged. Since the output of the UVS is a sixteen bit word which counts the number of photoelectrons (N_{pe}) produced by the UVS detector per tenth second, then according to the formula

$$N_{pe} = \frac{N_c}{1 - N_c \tau / T} \tag{1}$$

and if T = 1/10 sec

$$N_{pe} = \frac{N_c}{1 - 10 N_c \tau} \tag{2}$$

where N_{pe} is the actual number of photoelectrons per tenth second, N_c is the recorded number each tenth second interval, and τ is the total time required for the counting circuit to recover from detecting a count; i.e., τ is the dead time of the UVS measuring circuit. The value of τ has been chosen so that the product $10 N_c \tau$ will be much less than 1 for anticipated signals from the lunar atmosphere and $N_{pe} = N_c$. This level (i.e., $N_c \tau \ll 0.1$) can also be achieved with the UV calibration beam. However, the premonochromator beam can be increased in intensity to the level at which $N_c\tau$ (τ being about 1.6μs and N_c having a maximum value of about 60,000 per tenth second) approaches the value of 0.1. Thus the calibration equipment can experimentally determine the value of τ. It should be noted that the value of τ has been chosen to provide a linear relationship between N_{pe} and N_c in the range of signal strength anticipated from the lunar atmosphere, but also provides an extended range which is useful to measure the lunar albedo. For example if $N_c \approx 60,000$ and $\tau = 1.6$ μs, the value of $N_{pe} = 25\ N_c$.

Assuming for the moment that we are operating in the linear range, i.e., $N_{pe} = N_c$, we have the simple relationship between the input signal $I_{o\lambda}$ which can be recorded in photons per tenth second, and the UVS output signal which is in units of photoelectrons per tenth second.

$$N_{pe} = N_{ph}\, Q_\lambda T_\lambda \qquad (3)$$

where Q_λ is the quantum efficiency at each wavelength of the UVS photomultiplier tube and T is the optical transmission of the UVS at each wavelength. Thus the calibration equipment has measured the product $Q_\lambda T_\lambda$ of the UVS.

To determine the sensitivity of the instrument to an atmospheric signal, we employ the spectrophotometer formula

$$S_{pe/sec} = \frac{B_s^\lambda A_s A_g Q_\lambda T_\lambda}{F^2} \qquad (4)$$

where the quantity A_s is the area of the entrance slit of the UVS (about 1.2 sq cm), A_g is the area of the UVS grating (about 100 sq cm), and F is the focal length of the UVS Ebert mirror. The brightness of the source B_s^{λ} is expressed in photons per second per cm^2 per steradian at wavelength λ, and S_{pe} is given in photoelectrons per second. Since the atmospheric source is extended, and emits over 4 π steradians it is most conveniently expressed in units of 10^6 photons per sec per 4 π steradians, which brightness unit is known as the Rayleigh, B_R^{λ}. Thus Eq. 4 becomes

$$S_{pe/sec} = \frac{B_R^{\lambda} \times 10^6 \, A_s A_g Q_{\lambda} T_{\lambda}}{4 \pi F^2} \qquad (5)$$

As an example, if $Q_{\lambda} T_{\lambda} = 10^{-2}$, a source of one Rayleigh brightness will give a signal of about 40 photoelectrons per second. For further reference a source of one Rayleigh in the lunar atmosphere at 1216A would indicate an atomic hydrogen density of about 100 atoms per cc at the lunar surface and a total weight of hydrògen in the entire lunar atmosphere of 100 pounds.

A further requirement for calibrating the UVS is to determine the average wavelength associated with each UVS datε word as outlined in Sec. 2.2.3 below. The method consists of projecting the output of the UV source without predispersion on to the UVS entrance slit by setting the premonochromator to the central order.

2. Outline of Calibration Activity.

2.1 Preliminary Preparation

2.1.1 Absolute Calibration of Reference Photomultiplier Tubes $RPMT_1$ and $RPMT_2$.

2.1.1.1 Each reference tube will be placed at the shortened exit slit of, a UV monochromator whose entrance slit is illuminated with a stable UV source. At each wavelength of interest, the reference PMT will be moved horizontally and vertically to determine the variation in response over the face of the photocathode. The PMT will be replaced with a photodiode which has been absolutely calibrated at the National Bureau of Standards (NBS) to provide a direct measurement of the PMT sensitivity at all wavelengths. The reference PMTs will then be reinstalled in the CTE. The electronic readout equipment for the CTE measurements will be the equipment used in the absolute calibration.

2.1.2 Vacuum Performance Check.

2.1.2.1 Before the UVS is installed, the CTE will be evacuated to at least 2×10^{-5} torr. The time required will be less than 2 hours. If this time is exceeded the system will be checked with a helium leak detector, and the leak eliminated.

2.1.3 Reference Beam Optical Check.

2.1.3.1 The UV source will be excited, the premonochromator set definitively at all wavelengths to be employed in the calibration and the transfer mirror manipulated to illuminate $RPMT_1$ and $RPMT_2$. This check will demonstrate that the reference tubes have not significantly changed in their relative sensitivity. If a relative change is observed, Step 2.1.1 will be repeated before calibration of the UVS proceeds or will be repeated immediately after a calibration. This check will also confirm that the UV source is in proper operating condition.

2.1.4 Vacuum Contamination Check.

2.1.4.1 The calibration beam will be put to the central position and the mirror rhomb inserted in the beam to illuminate $RPMT_1$. The rhomb will be removed and the beam redirected by the transfer mirror M_T to directly illuminate $RPMT_1$. This operation will be performed at $\lambda = 1216A$ and $\lambda = 1470A$. It will be performed at the beginning of the preliminary vacuum test and at the end of the test or after each 4 hours of vacuum operation. The test is a measure of the reflectivity of the mirror rhomb. Any significant decrease (5% or more) in the rhomb reflectivity would be an indication that the vacuum is inadequate or that contamination vapors are in the system. Two test mirrors in the UVS main chamber will provide a similar warning; they will be checked for contamination in a reflectometer before and after each UVS calibration. If this unlikely situation develops, it will be necessary to dismantle the CTE for the purpose of degreasing and replacement of pump oils. It is estimated that three days would be required for this operation. It should be re-emphasized that our previous experience indicates that such optical deterioration will not occur.

2.1.5 Standby Procedure.

2.1.5.1 Following the successful completion of the procedures 2.1.2, 2.1.3, and 2.1.4 the valve between the UVS chamber and the premonochromator chamber will be closed, the diffusion pump valves in the UVS chamber will be closed, and the UVS section of the CTE backfilled to atmospheric pressure with pre-purified water pumped bone dry nitrogen (PPN_2). The premonochromator section will be backfilled to about 1 mm pressure with PPN_2 with its diffusion pump valve closed. All diffusion pumps will remain in operating condition.

2.2 Outline of Calibration Procedures. (All handling and installation of the UVS will be done by APL personnel.)

2.2.1 The UVS will be placed in the UVS chamber of the CTE on four mounting pins on a two axis movable shelf. The UVS cables will be connected to the BTE by means of through vacuum wall connectors. The CTE main chamber and the premonochromator chamber will be sealed and evacuated to at least 2×10^{-5} torr. The UV source will be activated and the premonochromator set at one of at least 5 chosen monochromatic wavelengths in the range 1100 to 1800A. The number of photons in the premonochromator output beam will be measured by the reference photomultiplier tubes. The UVS will be turned on. The beam will be vertically centered on the entrance slit and scanned across the slit. This procedure will be repeated for at least 5 angular positions of the UVS so that the average value observed represents the integrated sensitivity over the full field of view for that wavelength. At least two other slit positions above and below the center will be similarly studied so that the integrated sensitivity can be determined when each of the exit slit mirrors is employed. All of the above tests will be repeated for at least four other wavelengths.

2.2.2 Only a few intensity levels will be needed to determine the value of τ. The electronic system will have been checked electrically with a pulse generator to determine τ. A few optical check points are desirable to confirm the electronic checks.

2.2.3 To determine the response curve of the UVS it will be necessary to set the premonochromator at the brightest feature of the UV source, and to measure the output of the UVS at various levels of attenuation of the source. The attenuation is accomplished by reducing the length of the premonochromator slit and by reducing the power exciting the UV source. Thus the values of τ (Eq. 2) can be determined, or more generally the relationship between the observed count rate and the rate at which photoelectrons are produced will be experimentally determined.

2.2.4 The response of the UVS vs wavelength will be initially obtained by setting the pre monochromator grating position in the zero order and aligning the beam on the center of the UVS slit. In this way the spectrum of the UV source, for which the wavelength of line emission features is known, can be directed to the UVS entrance slit. The UVS will be turned on for 10 scans and the signal count observed as a function of the wavelength. Thus we will be able to assign a wavelength value to each data word.

2.3 Reduction of Data

2.3.1 In order to precisely determine the number of counts produced by the calibration beam it is necessary to integrate the UVS output.

2.3.2 The sensitivity of the UVS at a given wavelength will be determined from an analysis of the count rates observed as a function of wavelength. Since the wavelength scan per 0.1 second sample is a reasonable fraction of the spectral slit width it is necessary to calculate a "synthetic" signal response as a function of time. This calculation is based on the UVS cam program and also corrects for the dead-time loss given by Equation (1). An example, Ly α for the Preprototype UVS flown on an Aerobee 350, is shown in Fig. 3, for two values of the initial scan wavelength. A comparison of the shape of the observed counting rate curve with the synthetic spectrum then provides the following information:

a) precise wavelength identification (to better than 0.2A)

b) direct measure of the spectral slit width

c) a check on the proper focus and alignment of the UVS

d) determination of the true spectral intensity at the detector.

Note, from Fig. 3, that the maximum observed counting rate is always smaller than that which would be obtained in an ideal ($\Delta\lambda \to O$)

2.3.3 The raw data (in the form of digital printouts, strip charts, digital tape, and readings recorded by the operator) will be retained in the Calibration Facility. A calibration report, including all significant test data, and the reduced spectral calibration curve will be prepared within 7 days following completion of each calibration and distributed to APL and MSC.

2.4 Schedule for Calibration Activity.

2.4.1 Calibrate Prototype before environmental testing.

2.4.2 Calibrate Prototype after environmental testing.

2.4.3 Perform cross calibration check on prototype at VOB (GSFC).

2.4.4 Calibrate Qual Unit before Qaulification Test environmental testing.

2.4.5 Calibrate Qual Unit after Qualification Test environmental testing.

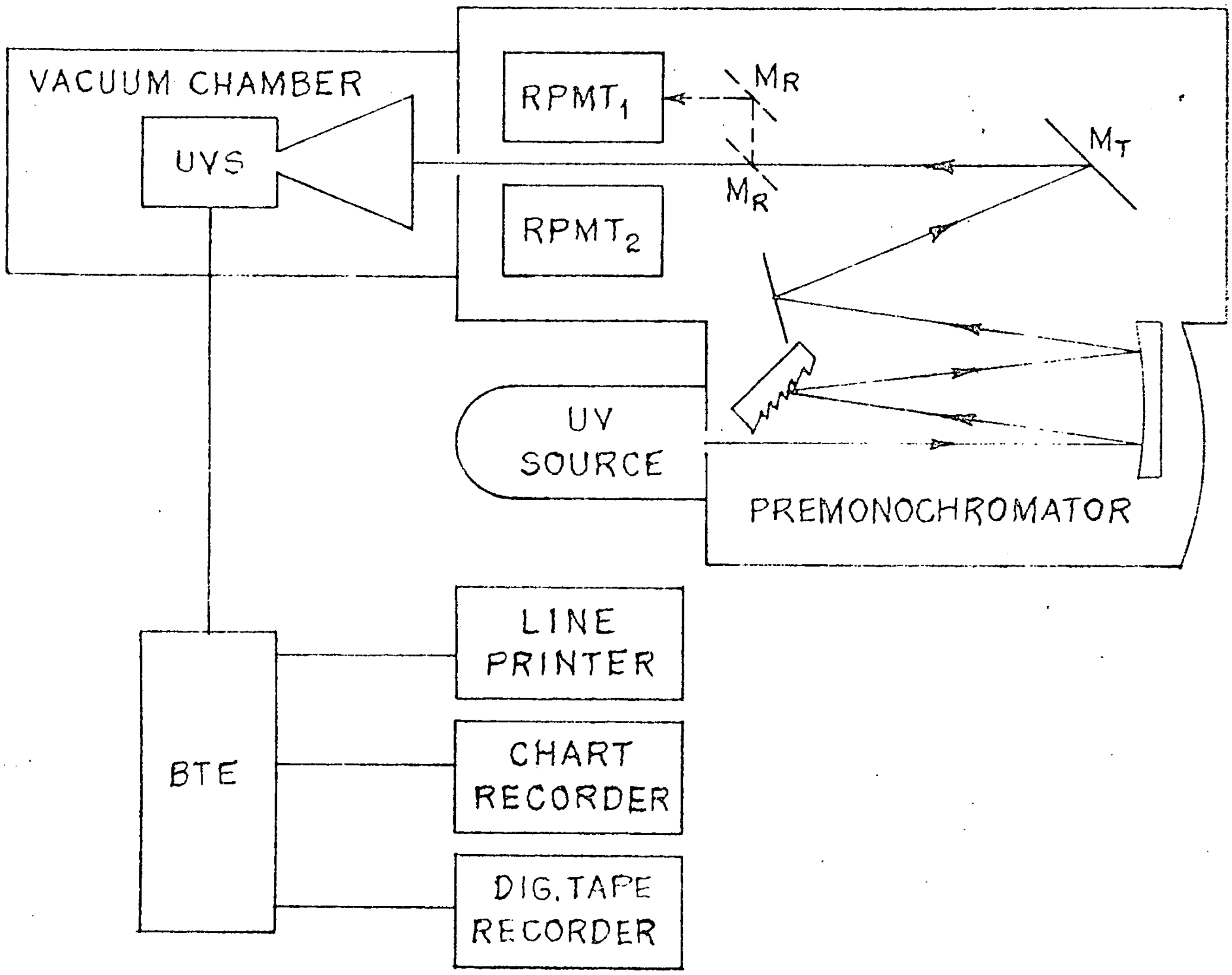
2.4.6 Calibrate Flight Unit 1 after environmental testing.

2.4.7 Cross calibrate (check) prototype at VOB (GSFC).

2.4.8 Calibrate Flight Unit 2 after environmental testing.

2.4.9 Calibrate Flight Unit 1 on return from KSC.

2.4.10 Calibrate Flight Unit 2 on return from KSC.



CALIBRATION TEST SET UP

FUNCTIONAL SCHEMATIC

FIG. 1

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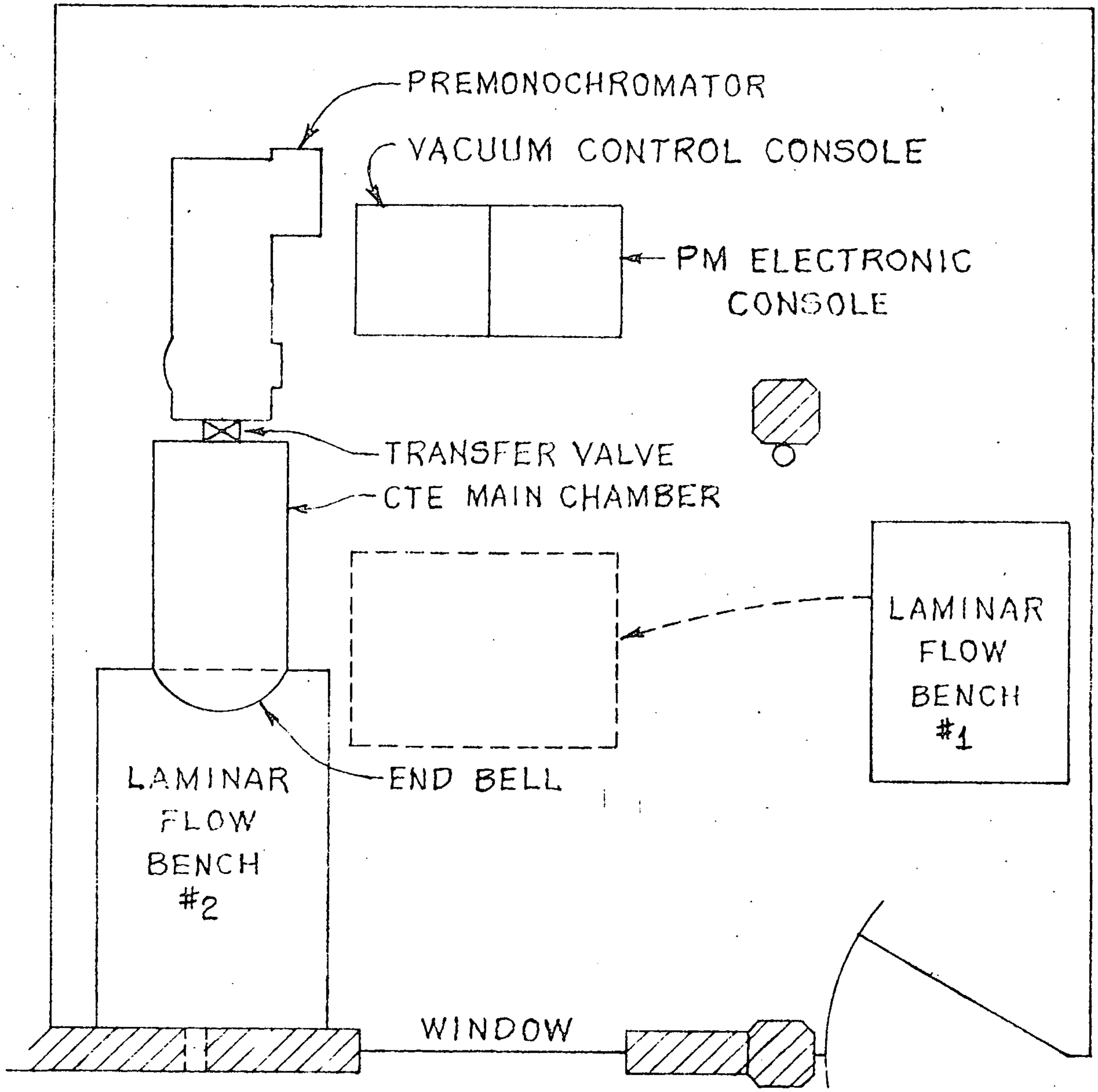

PLAN - WHITE ROOM
FUNCTIONAL LAYOUT

FIG. 2

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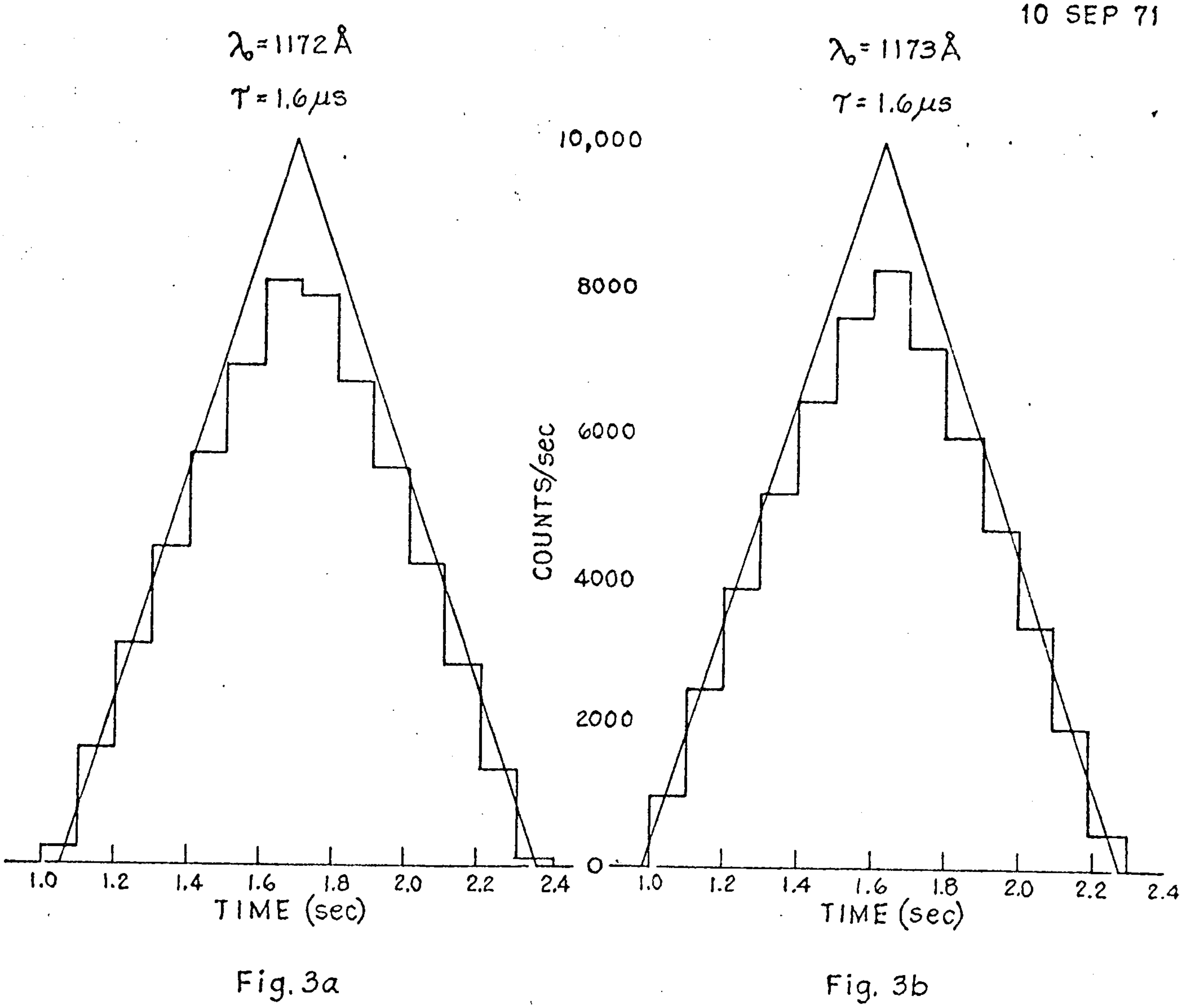

Fig. 3- Ly α Preprototype UVS Synthetic Spectra